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ABSTRACT

Solar system designs for 13 cities were optimized so as to minimize the life cycle cost over the assumed 20-year lifetime of the solar energy systems. A number of major assumptions were made regarding the solar system, type and use of building, financial considerations, and economic environment used in the design optimization. Seven optimum designs were developed for each city. In each case, comparisons were made with electric, oil, and natural gas water heating; and with electric resistive, electric heat pump, oil, and natural gas space heating. In each case, the backup conventional system used in the analysis was assumed to be the same as the competitive conventional system used in the analysis. To incorporate geographic variation, the study incorporated different climatic data, current 1976 incremental conventional fuel costs, building energy loads, and collector elevation angles for each city. Based on comparison with conventional energy costs, solar water heating and solar space heating installed at an equivalent system cost of $20 per square foot of collector are competitive today against electric resistance systems throughout most of the U.S. If the cost should be reduced to $10 per square foot by 1980 through a combination of technical innovations and incentives, solar hot water and heat would be economically competitive against all residential fuel types. (Author/MLF)

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Energy Research &
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An Economic Analysis of

Solar Water & Space Heating

ED158383

November 1976

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ABSTRACT

Based on comparison with conventional energy costs, solar water heating and solar space heating installed at an equivalent system cost of $20 per square foot of collector is competitive today against electric resistance systems throughout most of the U.S. If the system cost is reduced to $15 per square foot solar systems become competitive against oil hot water heating and/or oil and electric heat pump space heating in many cities. Finally, if the cost should be reduced to $10/ft^2 by 1980 through a combination of technical innovations and incentives, solar hot water and heat would be economically competitive against all residential fuel types.

Solar system designs for 13 cities were optimized so as to minimize the life cycle cost over the assumed 20 year life time of the solar energy systems. The major assumptions regarding the solar system, type and use of building, financial considerations, and economic environment used in the design optimization included:

- State-of-the-art technical performance of solar hot water and heat system with water collectors;
- Incremental system cost - $20/ft.^{2} of installed collector, in addition to a complete conventional backup system capability.
- Annual maintenance cost = 2 percent of initial system cost, escalated at 6 percent per year;
- Collector size designed to minimize life-cycle costs (storage and solar load are dependent on collector size);
- New detached single-family residence;
- 1500 square foot, four person residence;
- Brick veneer, asphalt roof, 12 inches of attic insulation, 15 MPH wind factor;
- Mortgage: 30 year, 8.5 percent interest;
- Homeowner in 30 percent incremental tax bracket;

- Zero additional property tax on solar system;
- Inflation: 6 percent annually;
- Fuel price escalation: 10 percent annually for gas, oil and electricity.

Seven optimum designs were developed for each city. In each case, comparisons were made with electric, oil and natural gas water heating and with electric resistive, electric heat pump, oil and natural gas space heating. In each case, the back-up conventional system used in the analysis was assumed to be the same as the competitive conventional system used in the analysis.

To incorporate geographic variation, the study incorporated different climatic data, current 1976 incremental conventional fuel costs, building energy loads, and collector elevation angles for each city.

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INTRODUCTION

The purpose of this paper is to develop an economic analysis of solar hot water and space heating for 13 cities (Figure 1) which are representative of the expected variations in climatic data and fuel costs in the United States. For three cost scenarios, solar heating and hot water systems for a new single-family residence are compared with conventional systems using natural gas, fuel oil, electric resistance, or electric heat pumps. Solar cooling is not considered here.

As far as possible the most recent regional energy price data were used in order to identify regions and conditions where solar heating and hot water can currently compete with conventional heating and hot water systems on the basis of life cycle cost. Life cycle cost provides a measure of the total costs of owning and operating a system over the life of the system rather than focusing solely on the initial cost of the system. Almost invariably, the initial costs of solar systems will be higher than conventional systems, however, in many cases, the annual savings accrued through the use of solar systems will pay back the increased initial cost. In addition to the payback period, the years before the first annual savings occur is used to further quantify the economic desirability of a solar system.

To assess the impact of potential cost reduction from engineering improvements or financial incentives, three cost scenarios are examined.

- Installed solar system costs of $\$20/ft^2$ and current (1976) fuel costs for electricity, oil and gas.

- Installed solar system costs of $\$15/ft^2$ and current (1976) fuel costs for electricity, oil and gas.

- Installed solar system costs of $\$10/ft^2$ and escalated (1980) fuel costs for electricity, oil and gas.

FIGURE 1
REPRESENTATIVE CITIES CONSIDERED

DESCRIPTION OF THE SOLAR SYSTEM

The solar system design used for this analysis is depicted in Figure 2. In this system, a portion of the solar energy incident on the solar collector is transferred via a liquid heat transfer medium to the insulated thermal storage tank through the heat exchanger.* The heat transfer liquid is returned to the collector in a closed loop and the process continues. The hot water from the storage tank is used to heat water in the hot water tank to 140°F and is then returned to storage to be reheated. If the water temperature from the storage tank is too low or the water in the hot water tank is sufficiently warmed, the flow is cut off by the solenoid valve. If sufficient heat is not available from storage on demand, the auxiliary heater warms the water in the hot water tank. For space heating, the water from the storage tank is circulated through a water to air heat exchanger to warm air which is used for space heating. The water is then returned to the storage tank. If the temperature of the water coming from storage is not adequate to heat the house, supplemental heat is supplied to the water by the auxiliary heating unit prior to entering the water-to-air exchanger. If no heat is required for heating, the water flow is either diverted to the hot water tank or cut off completely by the solenoid valves.

*Only water collectors are considered in this analysis. Work is in progress, that will include air collectors and cooling application.

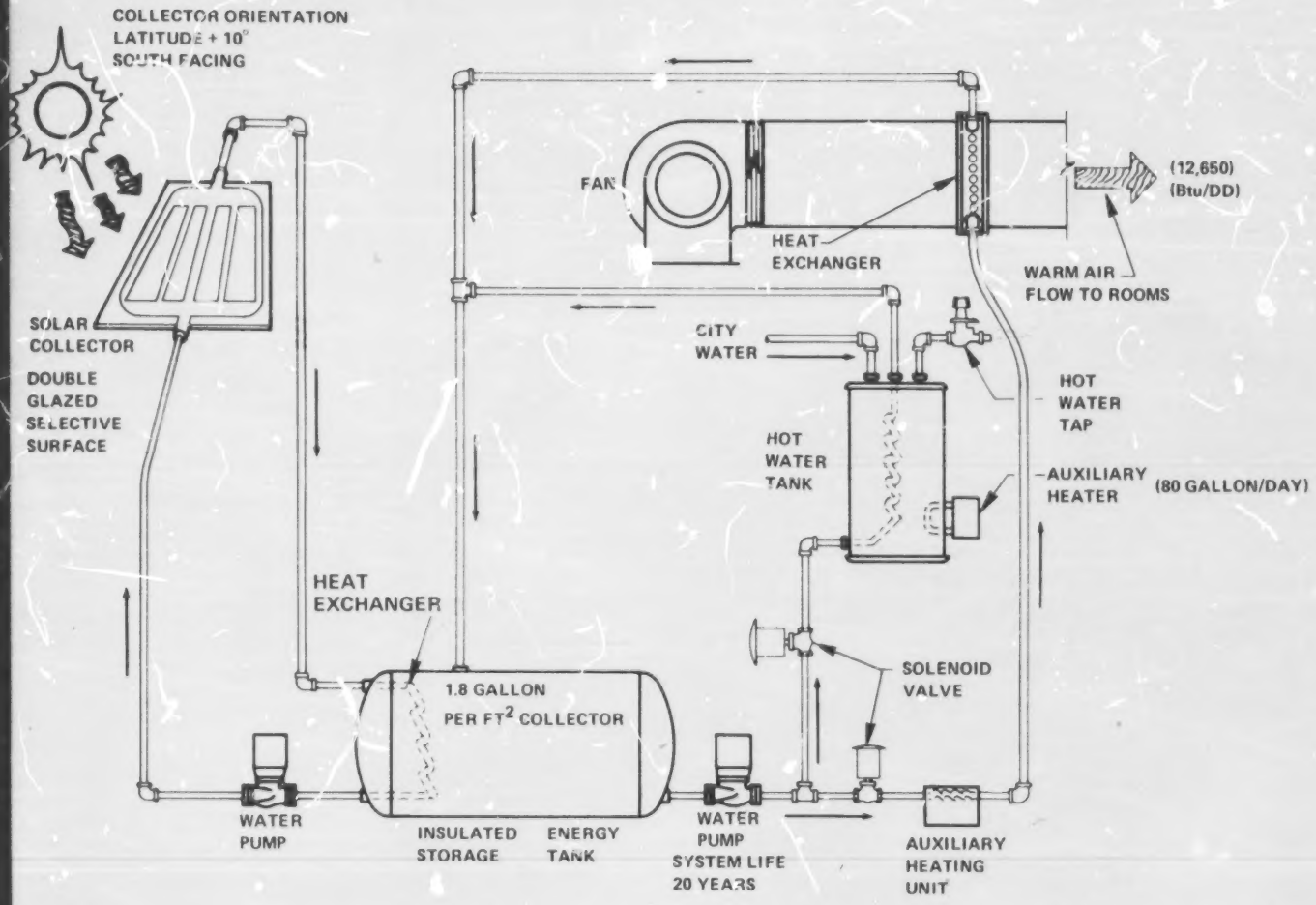


FIGURE 2
ILLUSTRATION OF SOLAR WATER AND SPACE HEATING SYSTEM

MAJOR ASSUMPTIONS

Only new residential construction (single family) is included in this analysis. (However, this analysis would apply to retrofit applications where 8.5 percent financing is available and no additional costs are incurred resulting from the retrofitting.) Since the heating and/or hot water system will be part of the original home purchase, terms of payment will be the same as the mortgage: in this case, an 8.5 percent mortgage over 30 years will be assumed. It is assumed that no additional down payment is required.

The building characteristics assumed are that of a residence for a family of 4; 1500 square feet, brick veneer, asphalt roof, storm windows, 12 inches of attic insulation; figured with 15 MPH wind factor. This house does not have an inordinate amount of insulation; however, it is relatively well insulated (roughly equivalent to the ASHRAE 90-75 standards) and results in a 12,650 Btu per degree day heating load to be combined with the daily hot water load of 56,500 Btu per day.

For the purpose of estimating the tax savings accrued by additional interest paid in financing the solar system, a combined state and Federal income tax of 30 percent is assumed. Current trends* in state and local legislation have favored not charging

*"Turning Toward the Sun," Volume I, National Conference of State Legislatures, Denver, Colorado, RANN Doc. No. NSF-RA-6-75-052.

property tax on the added value of the solar system, thus no incremental property tax is assumed for the solar system.

At present it is unclear what effects widespread use of solar heating and hot water systems will have on utility rate structures. For this analysis, the incremental utility prices for heating and hot water which are currently being charged will be used. The regional fuel costs and operating efficiencies of the conventional systems are discussed in more detail in Appendix A.

The solar system costs are assumed to be proportional to the square feet of collector installed. (Work is underway to determine the fixed and area dependent costs for different solar applications. Preliminary cost data is included in MITRE WP-11887, October, 1976.) The solar system costs reflect the incremental cost of the solar system and doesn't include the cost of a conventional system which would be capable of meeting the heating and hot water requirements of the house. Therefore, only the conventional fuel costs are used for comparison. The size of the system is dependent on the load, availability of useful solar energy, and fuel prices. Annual operating and maintenance cost for the first year is assumed to be 2 percent of the initial solar system cost and increases at the same rate as general inflation.

Inflation is assumed to continue at a rate of 6 percent annually. Fuel prices are assumed to escalate at a rate of 10 percent annually, or, at a rate 4 percent higher than inflation.

SYSTEM OPTIMIZATION AND ECONOMIC ANALYSIS

For each scenario and conventional system, an optimal solar system was determined for hot water only, and hot water and heat. This was done using a design program (FCHART) developed by the University of Wisconsin.* The program uses a set of design charts which estimate the thermal performance of a solar system based on the collector characteristics, storage, energy demands, and regional climatic data. Figure 3 illustrates the resulting changes in solar load as a function of collector area for solar hot water and heat in Washington, D.C. Using the results of the thermal analysis, an iterative procedure is used to select a collector area which minimizes the life cycle costs. The effect of varying collector area on the present values of the solar equipment cost, auxiliary fuel cost, and the combined total solar cost are shown in Figure 4. Once the optimal collector size has been determined the resulting thermal performance in Figure 5 can be displayed. Note that for our example in Washington, D.C., the optimal system size has excess collection capacity during the summer months when there is no heating load.

The design methodology used in FCHART is described in more detail in Appendix B and the characteristics of the individual solar designs are summarized by city in Appendix C.

*S.A. Klein, W.A. Beckman, and J.A. Duffie, "A Design Procedure for Solar Heating Systems", submitted for publication in Solar Energy (1975).

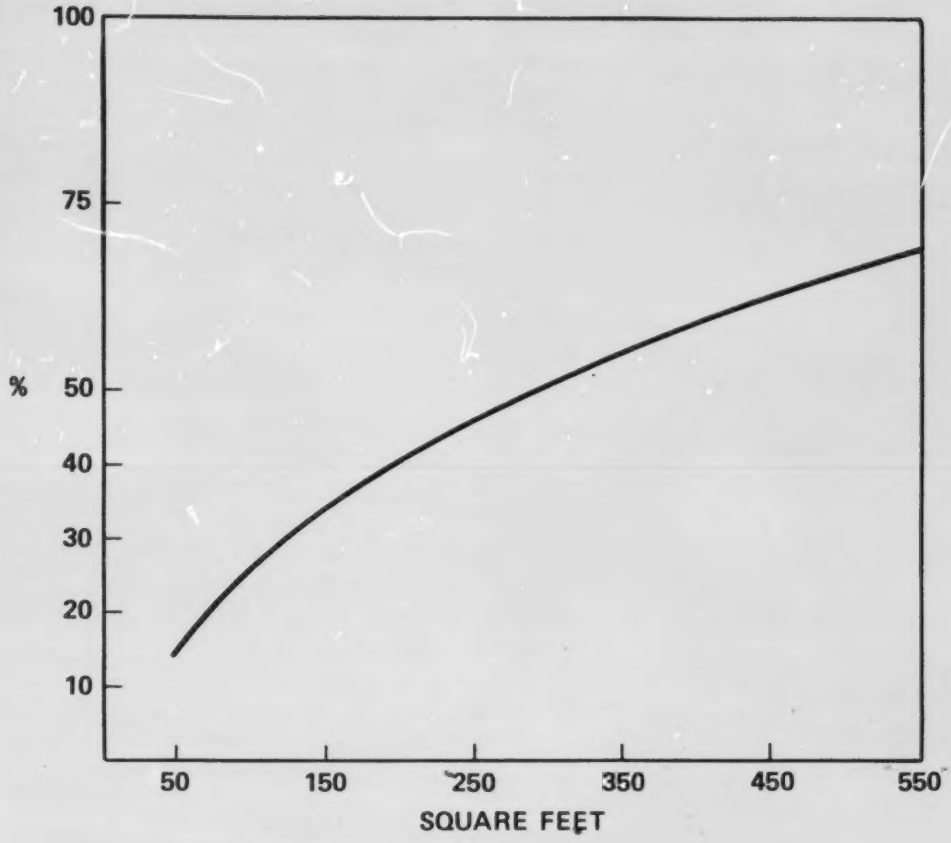


FIGURE 3
PERCENT OF ANNUAL HOT WATER AND HEATING LOAD
AS A FUNCTION OF COLLECTOR AREA
WASHINGTON- SINGLE FAMILY RESIDENCE

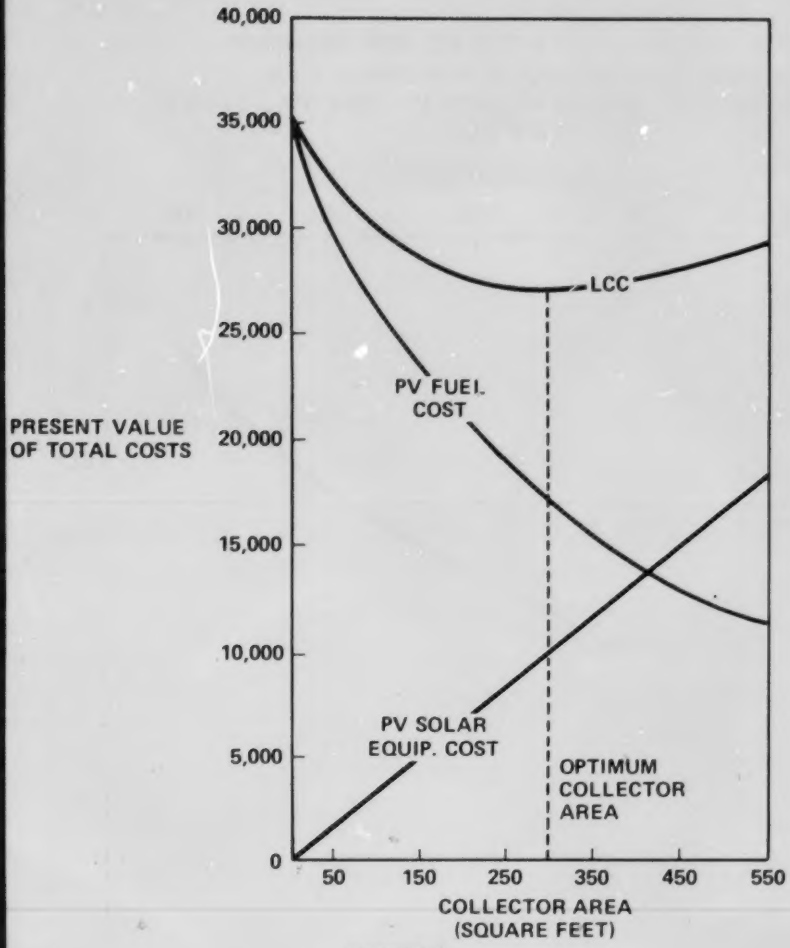


FIGURE 4

OPTIMIZATION OF COLLECTOR AREA:
WASHINGTON SINGLE FAMILY RESIDENCE

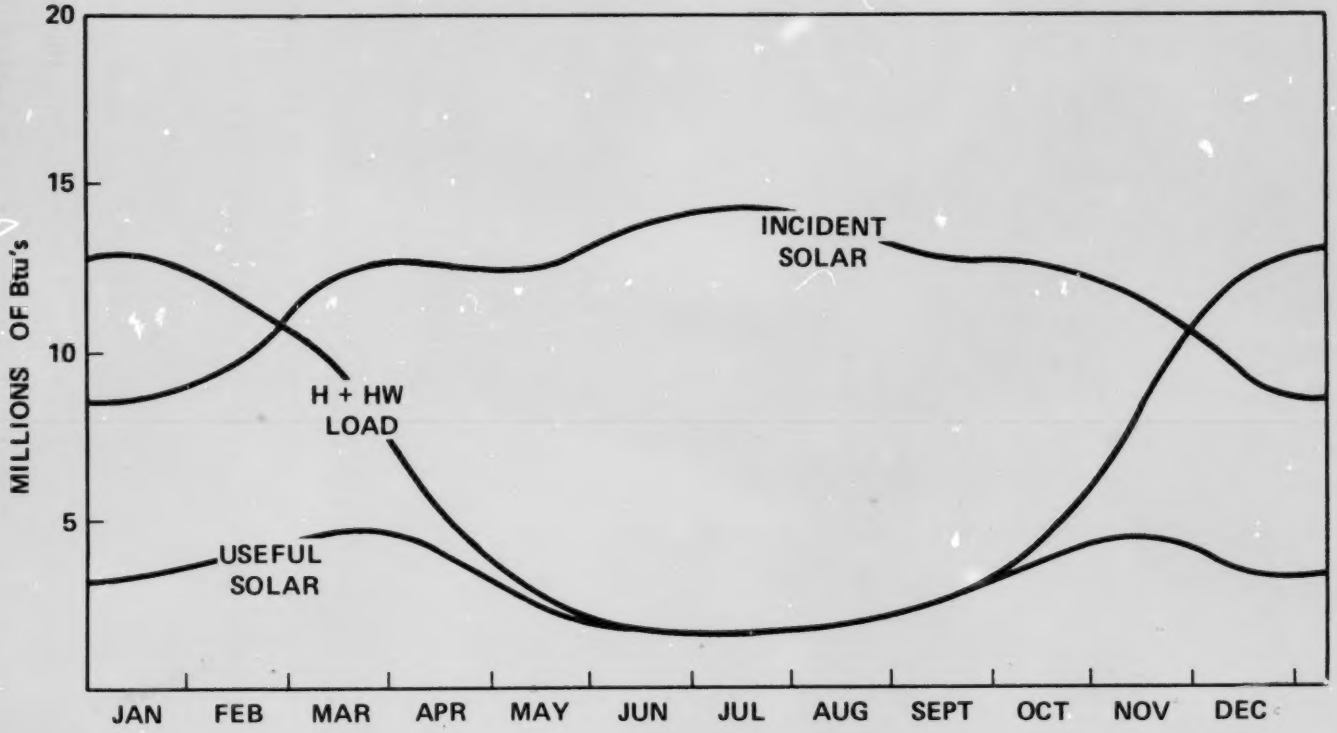


FIGURE 5
THERMAL PERFORMANCE OF SINGLE FAMILY WASHINGTON RESIDENCE
SOLAR HOT WATER AND HEAT vs ELECTRIC RESISTANCE
OPTIMIZED COLLECTOR AREA: 291 square feet; $20/square foot

MEASURES OF COST EFFECTIVENESS

For the purpose of this analysis two measures of cost effectiveness were considered:

- Positive Savings - Year in which solar system first becomes profitable; i.e., the annual conventional fuel bill without solar exceeds the annual fuel bill with solar plus the annual cost for the solar system.

- Payback - Year in which the compounded net savings equals the remaining principal on the mortgage for the solar system. Net savings are computed with respect to the fuel cost of the conventional backup system.

These measures were considered because they appear to be the measures with the most meaning for an ordinary property owner.

Positive savings will be of primary importance if the decision maker assumes that the unpaid mortgage for the solar system can be recovered upon the sale of the building. Positive savings can be viewed as similar to "dividends" paid on investment or interest paid on savings; however, taxes will not have to be paid on solar dividends whereas they would have to be paid on income from savings or investment. Thus, the dividends which a solar system might return in the form of savings is a very important factor for a prospective buyer considering his cash flow position. For this reason, one of the cost effectiveness criteria used here is the amount of time needed for the solar system to generate positive savings, or dividends. Figure 6 shows the annual expenses and resulting year of positive savings for an example.

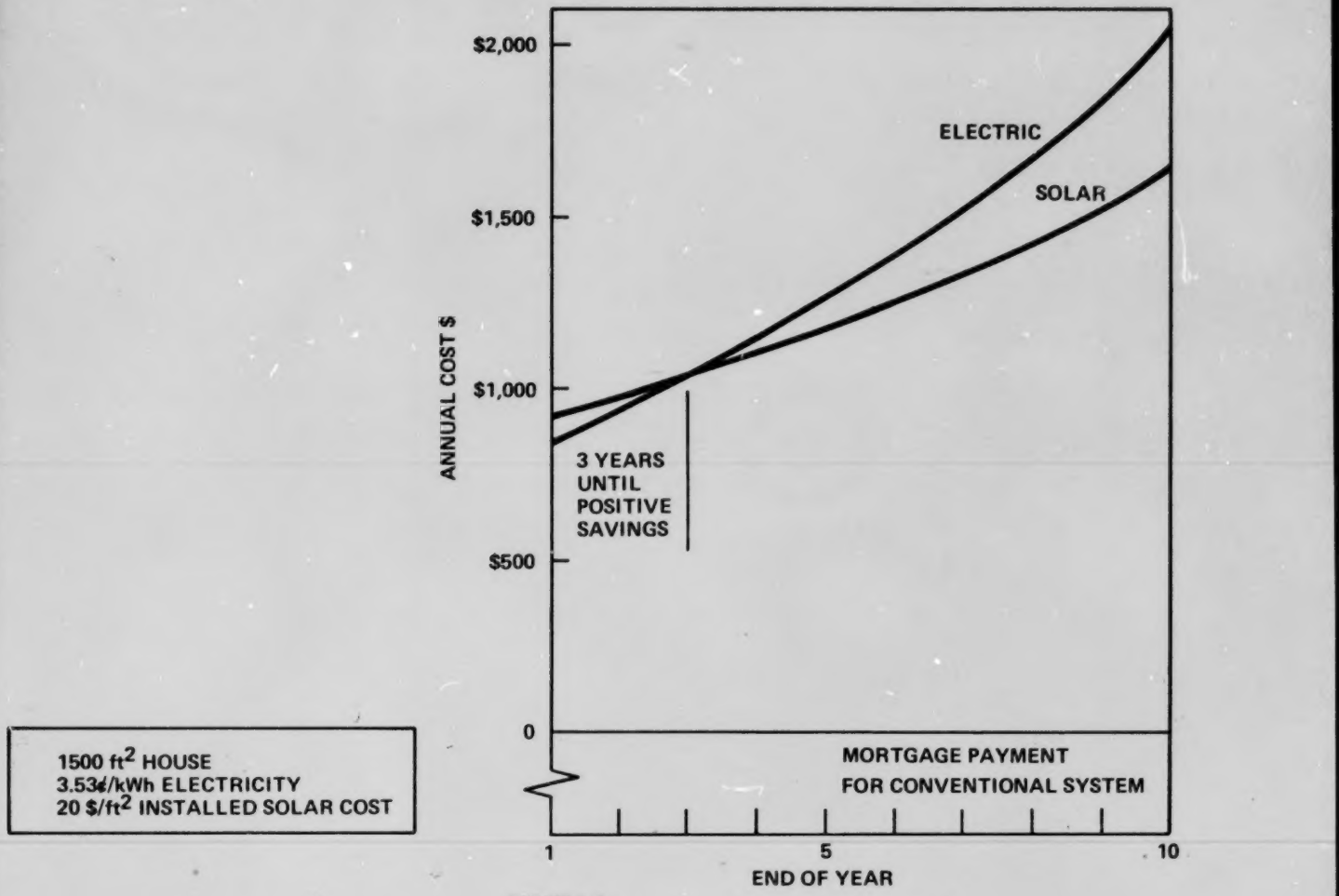


FIGURE 6
ILLUSTRATION OF ANNUAL EXPENSES FOR SOLAR vs ELECTRIC RESISTANCE

Payback is commonly used by investors to measure when the capital cost has been entirely recovered. Figure 7 illustrates the payback calculation using solar hot water and heat vs. electric resistance hot water and heat in Washington, D.C. as an example. Payback is the amount of time needed to accrue an adequate amount of money from fuel savings to pay off the remaining principal on that portion of the mortgage which financed the solar system. This measure of cost effectiveness would be more attractive to a prospective owner who does not believe the remaining equity in the solar system could be recovered in a resale. In the analysis, it was assumed that annual savings are applied toward prepayment of the principal on the solar portion of the mortgage. An additional 8-1/2 percent annual interest is collected on the solar savings, 8-1/2 percent being the rate on the mortgage being prepaid. Although it is unclear that the owner would actually prepay his mortgage, this is a useful measure to denote the point in time in which the solar system has compounded enough in savings to pay the remaining investment.

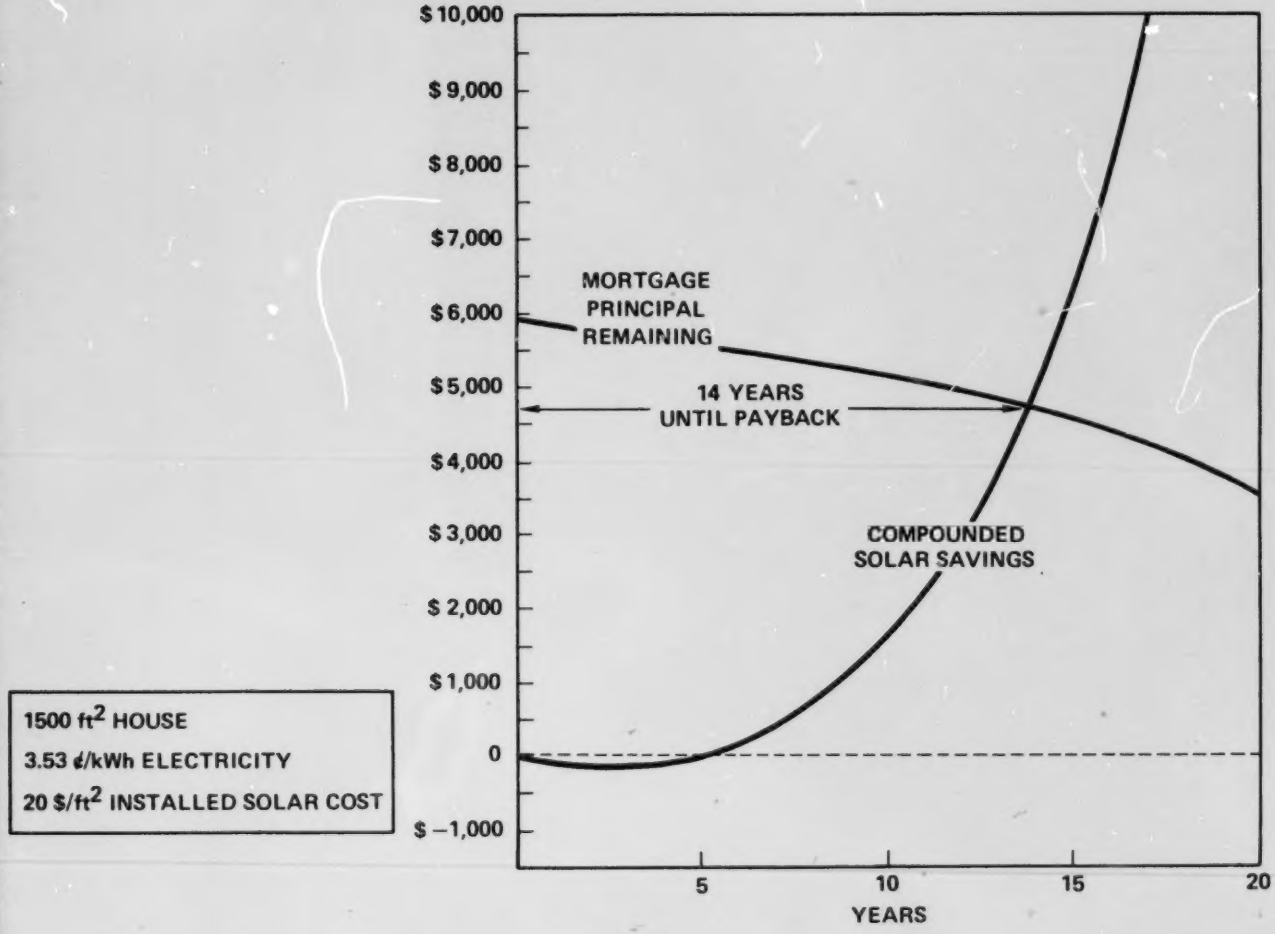


FIGURE 7
ILLUSTRATION OF PAYBACK CALCULATION FOR SOLAR vs ELECTRIC RESISTANCE

RESULTS OF ECONOMIC ANALYSIS

Table I contains the years to positive savings and payback for the 20 $/ft^2 scenario for solar hot water and heat. In some cases the solar systems which minimize the life cycle cost satisfy a very small percent of the load with solar. It is quite likely that the use of only area dependent costs of $20, $15, and $10/ft^2 without a fixed cost would be invalid for this end of the size range. The numerical values for cases with insufficient solar load have been replaced with asterisks. For this analysis the threshold for insufficient solar load has been arbitrarily assumed to be 50 percent for hot water only and 40 percent for hot water and heat. The detailed results for all three scenarios are contained in Appendix D.

The general impact of the scenarios is summarized in Tables II-IV, using the definition that:

> A system is economic if positive savings occur in 5 years or less <u>or</u> payback occurs in 15 years or less.

We recognize that this definition of "economic" is arbitrary. It was chosen as a point of departure for relative comparison. Appendix C summarizes in detail the optimal designs for each city. Data from the thermal and economic analysis are shown in Appendix E so that the reader can evaluate solar viability for himself.*

In the 20 $/ft^2 scenario, solar systems are competitive against electric resistance in 12 out of 13 cities. If the current costs

*Due to its bulk Appendix E has been bound separately and is available from the National Technical Information Service on request.

could be reduced to 15 $/ft^2 through incentives or as a result of mass production and/or improved designs, solar hot water systems would be competitive with oil in 5 out of 13 cities. Solar hot water and heat would be economically competitive with the electric heat pump in 5 out of 13 cities and oil in 6 out of 13 cities. Finally, if the system costs should be reduced to 10 $/ft^2 by 1980, solar hot water would be economically competitive against all fuel types in all but the most adverse conditions. Solar hot water and heat would be economically competitive against oil in all cities studied, electric resistance and the heat pump everywhere except Seattle, and gas in 9 out of 13 cities.

TABLE I

ECONOMICS OF SOLAR HOT WATER AND HEAT
CURRENT STATUS - 20 $/FT^2 INSTALLED SYSTEM COST

	YEARS TO POSITIVE SAVINGS				YEARS TO PAYBACK			
	ELECT.	H.P.	OIL	GAS	ELECT.	H.P.	OIL	GAS
ATLANTA	3	*	*	*	14	*	*	*
BISMARCK	4	7	7	*	14	19	18	*
BOSTON	3	*	*	*	14	*	*	*
CHARLESTON	1	*	7	*	11	*	19	*
COLUMBIA	3	*	*	*	14	*	*	*
DALLAS/FT. WORTH	3	*	*	*	13	*	*	*
GRAND JUNCTION	1	6	6	*	12	17	17	*
LOS ANGELES	1	7	7	*	10	19	19	*
MADISON	3	*	*	*	14	*	*	*
MIAMI	1	8	7	*	9	20	19	*
NEW YORK CITY	1	*	*	*	12	*	*	*
SEATTLE	*	*	*	*	*	*	*	*
WASHINGTON, D.C.	4	*	*	*	14	*	*	*

TABLE II
SOLAR ECONOMICS FOR 20 $/FT INSTALLED COST

DEFINITION: A SYSTEM IS ECONOMIC IF POSITIVE SAVINGS OCCUR IN 5 YEARS OR LESS OR PAYBACK OCCURS IN 15 YEARS OR LESS. Y = YES

	HOT WATER			HOT WATER AND HEAT			
	ELECT.	OIL	GAS	ELECT.	H.P.	OIL	GAS
ATLANTA	Y			Y			
BISMARCK	Y			Y			
BOSTON	Y			Y			
CHARLESTON	Y			Y			
COLUMBIA	Y			Y			
DALLAS/FT. WORTH	Y			Y			
GRAND JUNCTION	Y	Y		Y			
LOS ANGELES	Y			Y			
MADISON	Y			Y			
MIAMI	Y			Y			
NEW YORK CITY	Y			Y			
SEATTLE							
WASHINGTON, D.C.	Y			Y			

TABLE III
ECONOMICS OF SOLAR HOT WATER AND HEAT SOLAR ECONOMICS FOR 15 $/FT^2 INSTALLED COST

DEFINITION: A SYSTEM IS ECONOMIC IF POSITIVE SAVINGS OCCUR IN 5 YEARS OR LESS OR PAYBACK OCCURS IN 15 YEARS OR LESS. Y = YES.

	HOT WATER			HOT WATER AND HEAT			
	ELECT.	OIL	GAS	ELECT.	H.P.	OIL	GAS
ATLANTA	Y			Y		Y	
BISMARCK	Y	Y		Y	Y	Y	
BOSTON	Y			Y			
CHARLESTON	Y	Y		Y		Y	
COLUMBIA	Y			Y			
DALLAS/FT. WORTH	Y			Y			
GRAND JUNCTION	Y	Y		Y	Y	Y	
LOS ANGELES	Y	Y		Y	Y	Y	
MADISON	Y			Y	Y		
MIAMI	Y	Y		Y		Y	
NEW YORK CITY	Y			Y	Y		
SEATTLE							
WASHINGTON, D.C.	Y			Y			

TABLE IV
ECONOMICS OF SOLAR HOT WATER AND HEAT SOLAR ECONOMICS FOR 10 $/FT^2 INSTALLED COST IN 1980

DEFINITION: A SYSTEM IS ECONOMIC IF POSITIVE SAVINGS OCCUR IN 5 YEARS OR LESS OR PAYBACK OCCURS IN 15 YEARS OR LESS. Y = YES.

	HOT WATER			HOT WATER AND HEAT			
	ELECT.	OIL	GAS	ELECT.	H.P.	OIL	GAS
ATLANTA	Y	Y	Y	Y	Y	Y	Y
BISMARCK	Y	Y		Y	Y	Y	
BOSTON	Y	Y	Y	Y	Y	Y	Y
CHARLESTON	Y	Y		Y	Y	Y	
COLUMBIA	Y	Y		Y	Y	Y	
DALLAS/FT.WORTH	Y	Y	Y	Y	Y	Y	Y
GRAND JUNCTION	Y	Y	Y	Y	Y	Y	Y
LOS ANGELES	Y	Y	Y	Y	Y	Y	Y
MADISON	Y	Y		Y	Y	Y	
MIAMI	Y	Y	Y	Y	Y	Y	Y
NEW YORK	Y	Y	Y	Y	Y	Y	Y
SEATTLE		Y				Y	Y
WASHINGTON, D.C.	Y	Y	Y	Y	Y	Y	Y

SENSITIVITY ANALYSIS

The preceding analysis and conclusions have been based on a single set of assumptions. Although the assumptions are intended to be reasonable, it would be presumptuous to assume that the future will match any preconceived set of estimates. Changes in the assumptions will have two major ramifications. First, the actual savings for a solar home corresponding to one of our optimized designs may differ from the estimates shown in Appendices C and E. This represents a risk to a potential investor that has already purchased a system. Second, if the changes are perceived before the construction of the building then the optimal solar system design will change. This represents an uncertainty about the likely competitiveness of the solar applications.

To measure the potential risk inherent in using the optimized designs, a series of variations from our standard example of solar hot water and heat for Washington D.C. were examined. For a fixed collector size of 291 ft^2 the following cases were examined:

- 6% and 8% fuel escalation (6% inflation)
- $\pm$ 20% change in the heat load
- 5% inflation and 9% fuel escalation
- 7% inflation and 11% fuel escalation
- 0% and 1% maintenance.

These are plotted in Figure 8 around the reference point corresponding to:

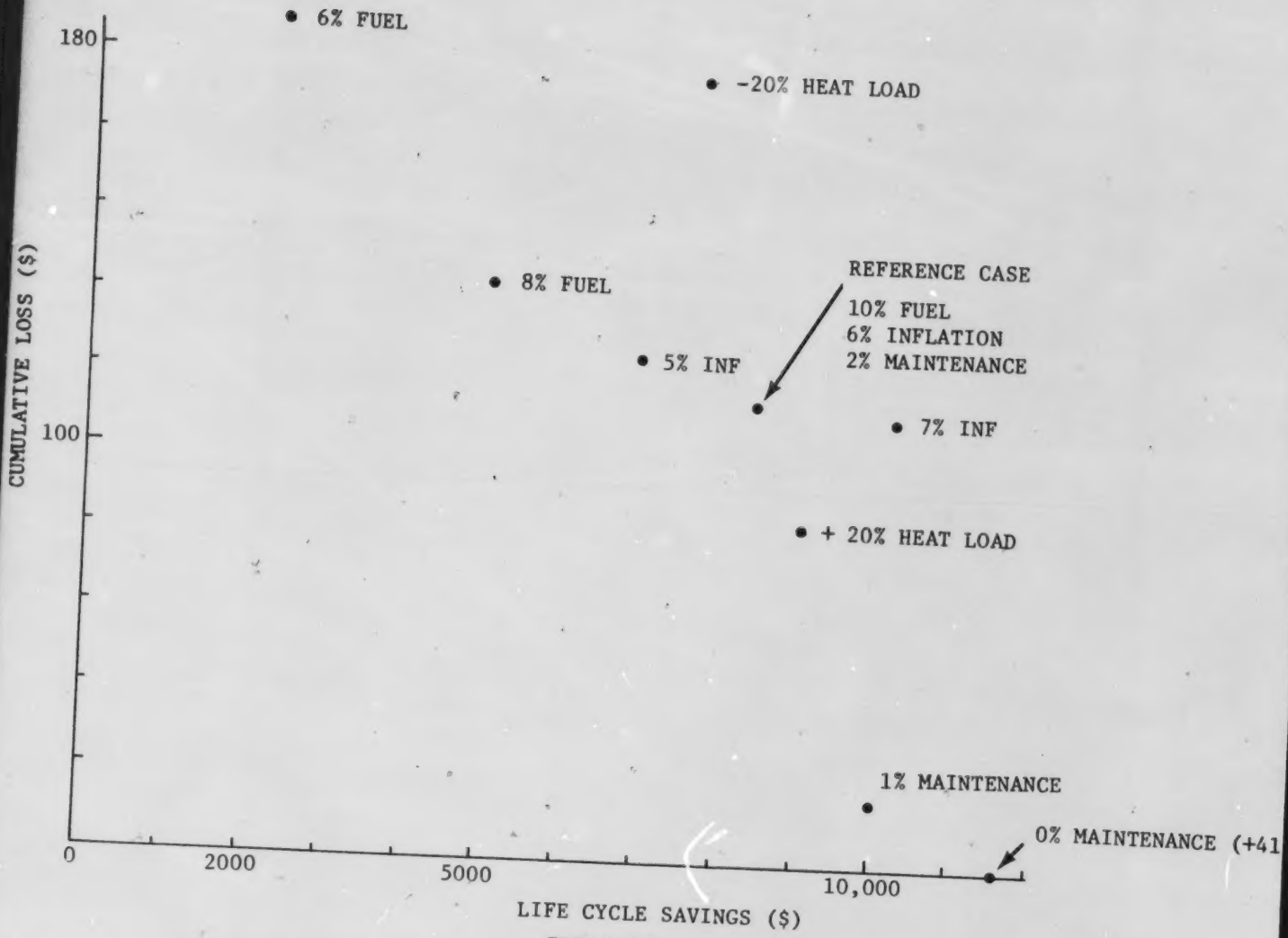


FIGURE 8
RISK ANALYSIS

- 6% inflation
- 10% fuel escalation
- 2% maintenance.

The life cycle savings (solar-conventional) and cumulative loss (the sum of the negative cash flow before positive savings occur) have been selected as the axes to reflect the short term and life cycle impacts. Moving up and to the left is the worst situation. As can be seen from the figure decreasing fuel escalation to 6 percent is the worst case examined. If the system designs are more reliable than our estimates and the maintenance is 1 percent or less then the cash flow for the solar systems are greatly improved. In general, none of the cases examined caused a large degradation in the system's economic competitiveness. If these results hold true for all the cases, this would be most reassuring to prospective owners of solar systems for hot water and heat.

The optimal design is sensitive to relatively small changes in the assumptions. Recall from Figure 4 that the life cycle cost vs. size curve was quite flat in the region of the optimum for our example. This means that relatively large changes in size will have proportionately smaller changes in cost. In an analogous manner, small variations in some of the parameters will shift the curve significantly.

To explore this sensitivity in collector size, the following cases were optimized for solar hot water and heat in Washington, D.C.:

- o 2%, 1%, and 0% maintenance
- o 2 1/2%, 3 1/2%, and 4 1/2% net discount rate
- o 30%, 25%, and 20% tax rate
- o 10%, 8%, and 6% fuel escalation
- o 10%, 8 1/2 %, and 7% mortgage rate.

These are plotted in Figure 9. For each single factor the points are straight line segments converging at the reference case. As before, fuel escalation and maintenance are the critical factors. A 6 percent fuel escalation (instead of 10 percent) causes a 45 percent reduction in collector area and a 65 percent reduction in life cycle savings. Conversely a maintenance free system would be 55 percent larger and 40 percent more profitable. The other factors cause changes of less than 20 percent in the optimum collector area. This level of accuracy is probably well within the limits of the current ability to design solar systems.

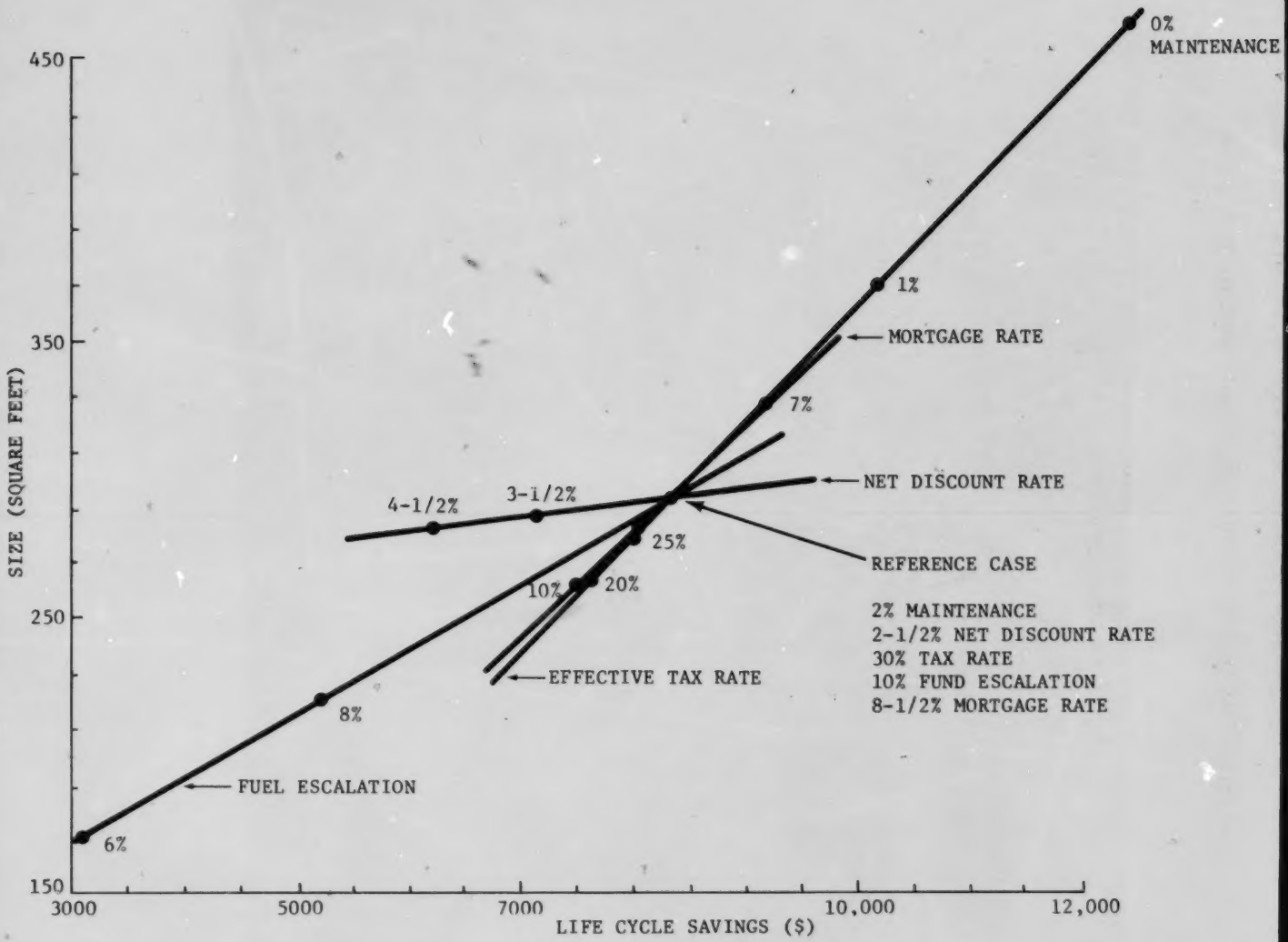


FIGURE 9
DESIGN SENSITIVITY

APPENDIX A

REGIONAL ENERGY PRICES AND COST OF DELIVERED HEAT

The costs of conventional energy sources for hot water and heating applications are contained in Table A-I. The data for electricity and natural gas were obtained in a telephone survey of the individual utilities in July 1976.

Natural gas prices per million Btu include the marginal rate corresponding to the 50 to 100 therm level of consumption in a declining rate block schedule. The prices include any state/local tax and purchase gas adjustments. It is assumed that 50 to 100 therms represent a base consumption level for residential users with this type of home.

Electricity prices per million Btu include the marginal rate corresponding to the 500 to 750 kWh level of consumption in a declining rate block schedule for the winter season in 1975. These prices include any state/local tax and fuel cost adjustments. It is assumed that the 500 to 750 kWh block represents a base consumption level by residential users.

The average price of 100 gallons of #2 grade oil for the city of New York as of January 1, 1976 was obtained from the Bureau of Labor Statistics. The regional oil cost factors presented in the GE Phase 1 report, Parametric Study for Defining the Number of Residential and Non-Residential Applications of Solar Heating and

Cooling (January, 1976), were used to derive fuel oil costs for each of the other 12 cities.

The cost of delivered heat for each conventional fuel system was put on a comparable cost basis as depicted in Figure A-1. The fuel costs were adjusted with Coefficients of Performance (COP's) for electric resistance heating and hot water, gas heating and hot water, oil heating, and regionally specific heat pump COP's. Heat Pump COP's represent annual averages and were derived from the GE Phase 0 Study. Solar Heating and Cooling of Buildings, Phase 0, Feasibility and Planning Study, Final Report, Vol II.

Table A-II summarizes the cost of energy which is actually delivered for hot water and heat.

TABLE A-1
COST OF CONVENTIONAL ENERGY SOURCES

	ELECTRICITY[1] (¢/kWh)	OIL[2] (¢/GAL.)	NATURAL GAS[3] ($/MMBTU)
ATLANTA	2.80	43.1	1.53
BISMARCK	2.81	48.3	1.12
BOSTON	4.60	45.7	2.82
CHARLESTON	3.87	44.8	1.27
COLUMBIA	3.49	40.5	1.21
DALLAS/FT. WORTH	2.54	34.5	1.70
GRAND JUNCTION	3.36	46.6	1.27
LOS ANGELES	3.88	36.6	1.28
MADISON	3.69	46.1	1.33
MIAMI	4.00	36.2	1.35
NEW YORK CITY	6.36	43.1	3.55
SEATTLE	.86	44.4	2.42
WASHINGTON, D.C.	3.53	40.1	1.93

[1]TELEPHONE SURVEY OF UTILITIES, JULY 1976. WINTER RATE FOR 500-750 kWh.

[2]G.E. PHASE 1 STUDY ADJUSTED FOR JULY 1976 NYC FUEL COSTS.

[3]TELEPHONE SURVEY OF UTILITIES, JULY 1976. RATE FOR 50-100 THERMS.

ELECTRIC RESISTANCE:

$$(.0353\ \$/kWh)\left(\frac{kWh}{3413 \times 10^{-6}\ MMBtu}\right)\left(\frac{1}{.9\ COP}\right) = 11.48\ \$/MMBtu$$

NATURAL GAS:

$$(1.93\ \$/MMBtu)\left(\frac{1}{.6\ COP}\right) = 3.22\ \$/MMBtu$$

HOME HEATING OIL:

$$(.401\ \$/GAL.)\left(\frac{GAL.}{.141\ MMBtu}\right)\left(\frac{1}{.6\ COP}\right) = 4.74\ \$/MMBtu$$

HEAT PUMP:

$$(.0353\ \$/kWh)\left(\frac{kWh}{3413 \times 10^{-6}\ MMBtu}\right)\left(\frac{1}{2.1\ COP}\right) = 4.92\ \$/MMBtu$$

HEAT PUMP COP*:

ATLANTA	2.1	DALLAS-FT. WORTH	2.4	NYC	2.3
BISMARCK	1.5	GRAND JUNCTION	1.9	SEATTLE	2.4
BOSTON	2.0	LOS ANGELES	2.5	WASHINGTON D.C.	2.1
CHARLESTON	2.5	MADISON	1.6		
COLUMBIA	2.3	MIAMI	2.5		

* GE PHASE 0 REPORT

FIGURE A-1
METHOD FOR CONVERTING CONVENTIONAL FUEL COSTS INTO COSTS PER BTU—EXAMPLE FOR WASHINGTON, D.C.

TABLE A-II
COST OF DELIVERED HEAT - $/MMBTU

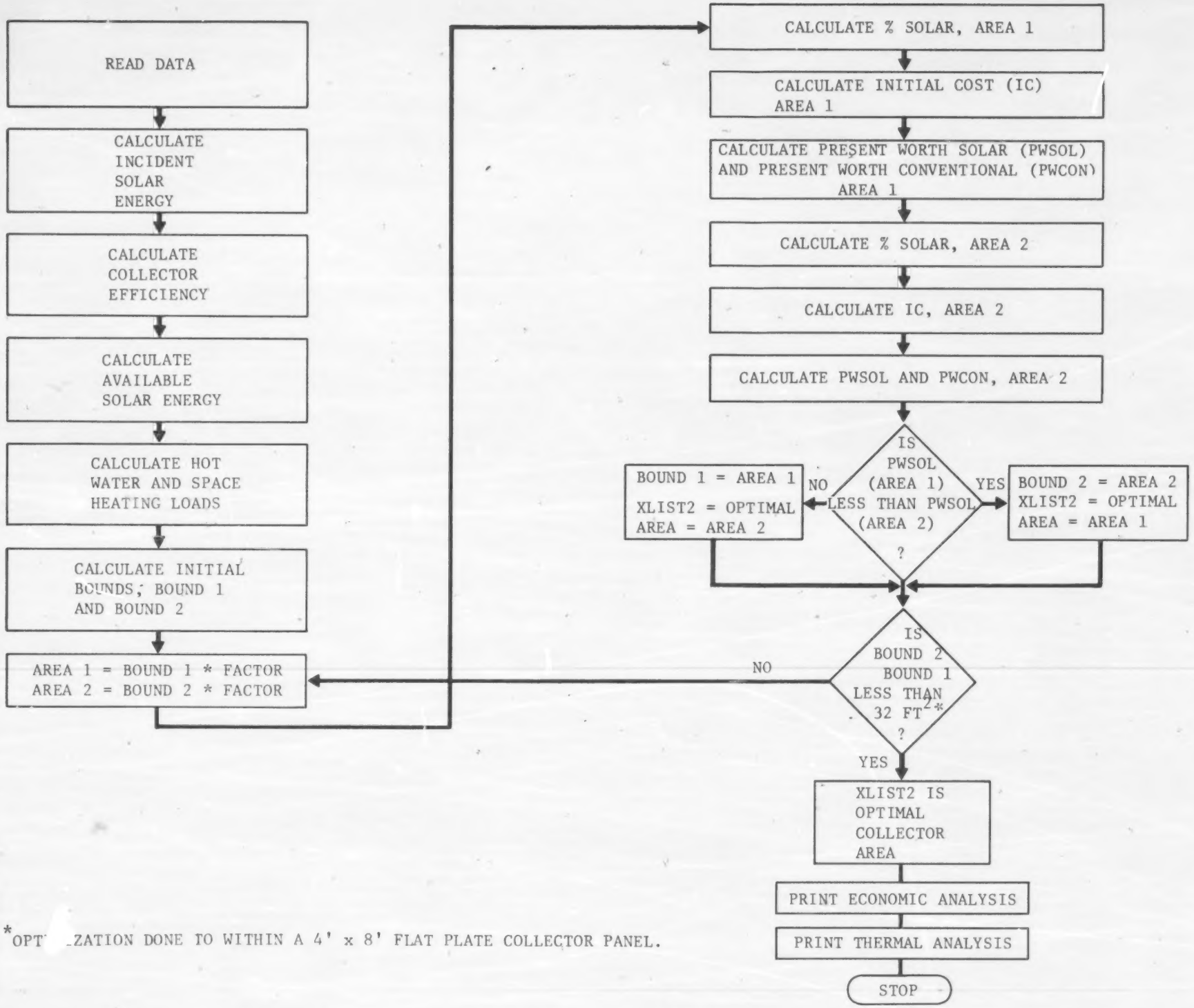
	ELECTRICITY	HEAT PUMP	OIL	GAS
ATLANTA	9.12	3.91	5.09	2.55
BISMARCK	9.14	5.49	5.71	1.87
BOSTON	14.97	6.74	5.40	4.70
CHARLESTON	12.59	4.54	5.30	2.12
COLUMBIA	11.36	4.45	4.79	2.02
DALLAS/FT. WORTH	8.26	3.10	4.08	2.83
GRAND JUNCTION	10.93	5.18	5.51	2.12
LOS ANGELES	12.63	4.55	4.33	2.13
MADISON	12.01	6.76	5.45	2.22
MIAMI	13.02	4.69	4.28	2.25
NEW YORK CITY	20.70	8.10	5.09	5.92
SEATTLE	2.79	1.05	5.25	4.03
WASHINGTON, D.C.	11.49	4.93	4.74	3.22

APPENDIX B

DESCRIPTION OF THE SOLAR SYSTEM DESIGN METHODOLOGY

The system designs were performed using a design program (FCHART) developed by the University of Wisconsin and modified by MITRE. FCHART is an interactive computer program used to calculate the thermal performance of solar space heating and domestic water heating systems. A general design procedure was developed at the University of Wisconsin from information gained from a simulation model capable of estimating the long term thermal performance of solar systems. The performance or design chart correlates the long term performance of solar heating systems to the system design parameters, building construction, and weather. When used with costs in a specific location, the design chart provides a method by which to determine the economically optimal solar space heating and domestic water heating system using air or water as the transfer fluid. A generalized flow chart of the program is given in Figure B-1.

FCHART requires weather and location data. Data is available for 112 cities in the United States and Canada. Monthly heating degree-day data and latitude are input for each location, In addition, building construction data, system design parameters, system costs, and economic data are input by the user. Figure B-2 illustrates the input format and paramaters used for the hot water and heating example for Washington, D.C.


READ DATA
CALCULATE INCIDENT SOLAR ENERGY
CALCULATE COLLECTOR EFFICIENCY
CALCULATE AVAILABLE SOLAR ENERGY
CALCULATE HOT WATER AND SPACE HEATING LOADS
CALCULATE INITIAL BOUNDS; BOUND 1 AND BOUND 2
AREA 1 = BOUND 1 * FACTOR
AREA 2 = BOUND 2 * FACTOR
CALCULATE % SOLAR, AREA 1
CALCULATE INITIAL COST (IC) AREA 1
CALCULATE PRESENT WORTH SOLAR (PWSOL) AND PRESENT WORTH CONVENTIONAL (PWCON) AREA 1
CALCULATE % SOLAR, AREA 2
CALCULATE IC, AREA 2
CALCULATE PWSOL AND PWCON, AREA 2
IS PWSOL (AREA 1) LESS THAN PWSOL (AREA 2) ?
NO
BOUND 1 = AREA 1
XLIST2 = OPTIMAL AREA = AREA 2
YES
BOUND 2 = AREA 2
XLIST2 = OPTIMAL AREA = AREA 1
IS BOUND 2 BOUND 1 LESS THAN 32 FT2* ?
NO
YES
XLIST2 IS OPTIMAL COLLECTOR AREA
PRINT ECONOMIC ANALYSIS
PRINT THERMAL ANALYSIS
STOP

*OPTIMIZATION DONE TO WITHIN A 4' x 8' FLAT PLATE COLLECTOR PANEL.

FIGURE B-1
FCHART FLOWCHART

B-3

SOLAR HEATING AND HOT WATER FOR WASHINGTON, D.C.
VERSUS ELECTRIC RESISTANCE CONVENTIONAL SYSTEM

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM#1,LIQUID SYSTEM#2.....	2.00	
2	COLLECTOR AREA.....	291.00	FT2
3	FRPRIME-TAU-ALPHA PRODUCT%NORMAL INCIDENCE<..	0.70	
4	FRPRIME-UL PRODUCT.....	0.83	BTU/H-F-F2
5	NUMBER OF TRANSPARENT COVERS.....	2.00	
6	COLLECTOR SLOPE.....	48.51	DEGREES
7	AZIMUTH ANGLE %E.G. SOUTH#0, WEST#90<.....	0.00	DEGREES
8	STORAGE CAPACITY.....	15.00	BTU/F-FT2
9	EFFECTIVE BUILDING UA.....	526.60	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION.....	0.0	BTU/DAY
11	HOT WATER USAGE.....	80.00	GAL/DAY
12	WATER SET TEMPERATURE.....	140.00	F
13	WATER MAIN TEMPERATURE.....	51.80	F
14	CITY CALL NUMBER.....	100.00	
15	PRINT OUT BY MONTH#1, BY YEAR#2.....	1.00	
16	ECONOMIC ANALYSIS YES#1, NO#2.....	1.00	

B-5

FIGURE B-2
EXAMPLE OF SOLAR SYSTEM DESIGN

SOLAR HEATING AND HOT WATER FOR WASHINGTON, D.C.
VERSUS ELECTRIC RESISTANCE CONVENTIONAL SYSTEM (CONCLUDED)

17	USE OPTMZD. COLLECTOR AREA#1, SPECFD. AREA#2.	1.00	
18	PERIOD OF THE ECONOMIC ANALYSIS.....	20.00	YEARS
19	COLLECTOR AREA DEPENDENT SYSTEM COSTS.....	20.00	$/FT2 COLL
20	CONSTANT SOLAR COSTS.....	0.0	$
21	DOWN PAYMENT%_ OF ORIGINAL INVESTMENT<.....	0.0	_
22	ANNUAL INTEREST RATE ON MORTGAGE.....	8.50	
23	TERM OF MORTGAGE.....	30.00	YEARS
24	ANNUAL NOMINAL%MARKET< DISCOUNT RATE.....	2.50	_
25	EXPENSES%INSUR.,MAINT.< OF SYSTEM IN 1ST YEAR	2.00	%
26	ANNUAL _ INCREASE IN ABOVE EXPENSES.....	6.00	_
27	PRESENT COST OF AUXILIARY FUEL %CF<.....	11.49	$/MBTU
28	CF RISE' LINEAR#1,_/YR#2,SEQ. OF VALUES#3....	2.00	
29	IF 1, WHAT IS THE SLOPE OF CF INCREASE	0.50	$/MBTU-YR
30	IF 2, WHAT IS THE ANNUAL RATE OF CF RISE.....	10.00	_
31	ECONOMIC PRINT OUT BY YEAR#1, CUMULATIVE#2...	1.00	
32	EFFECTIVE FEDERAL-STATE INCOME TAX RATE.....	30.00	_
33	TRUE PROP. TAX RATE PER $ OF ORGINAL INVEST..	0.0	_
34	INCOME PRODUCING BUILDING YES#1,NO#2.....	2.00	
39	FUEL ADJUSTMENT FACTOR.....	0.0	

B-6

FIGURE B-2 (CONCLUDED)

For each month the incident solar energy on the collection face is calculated from an adjustment of average daily radiation on a horizontal surface for the collection tilt and azimuth angle, and the monthly design chart value.

The collector efficiency is calcuated using the values of F' Tα (the product of the collector efficiency factor and the product of the glazing transmissivity and the absorber's absorptivity) and F'UL (the product of the overall heat loss coefficient and the collector efficiency factor). If flat plate collector experimental performance data is plotted as collector efficiency (η) vs $(T_{in}-T_{amb})/S$ a straight line can usually be fitted to the data points. An example of an efficiency curve is shown in Figure B-3 for the collector used with F'Tα = .75 and F'UL = 1.0. Assuming that the data was taken with a specified fluid capacitance rate and with all solar radiation at normal incidence to the plane of the collector, the intercept of the straight line with the η-axis is F(Tα).F is the the collector heat removal factor; (Tα) is the transmittance absorptance product of the collector cover system at normal incidence.

FU_L is the slope of the straight line η vs $(T_{in}-T_{amb})/S$ plot, if the plot is obtained as described above.

F' is a corrected F which in liquid based systems accounts for the effect of the collector-to-storage heat exchanger. In air systems F = F' since there is no heat exchanger.

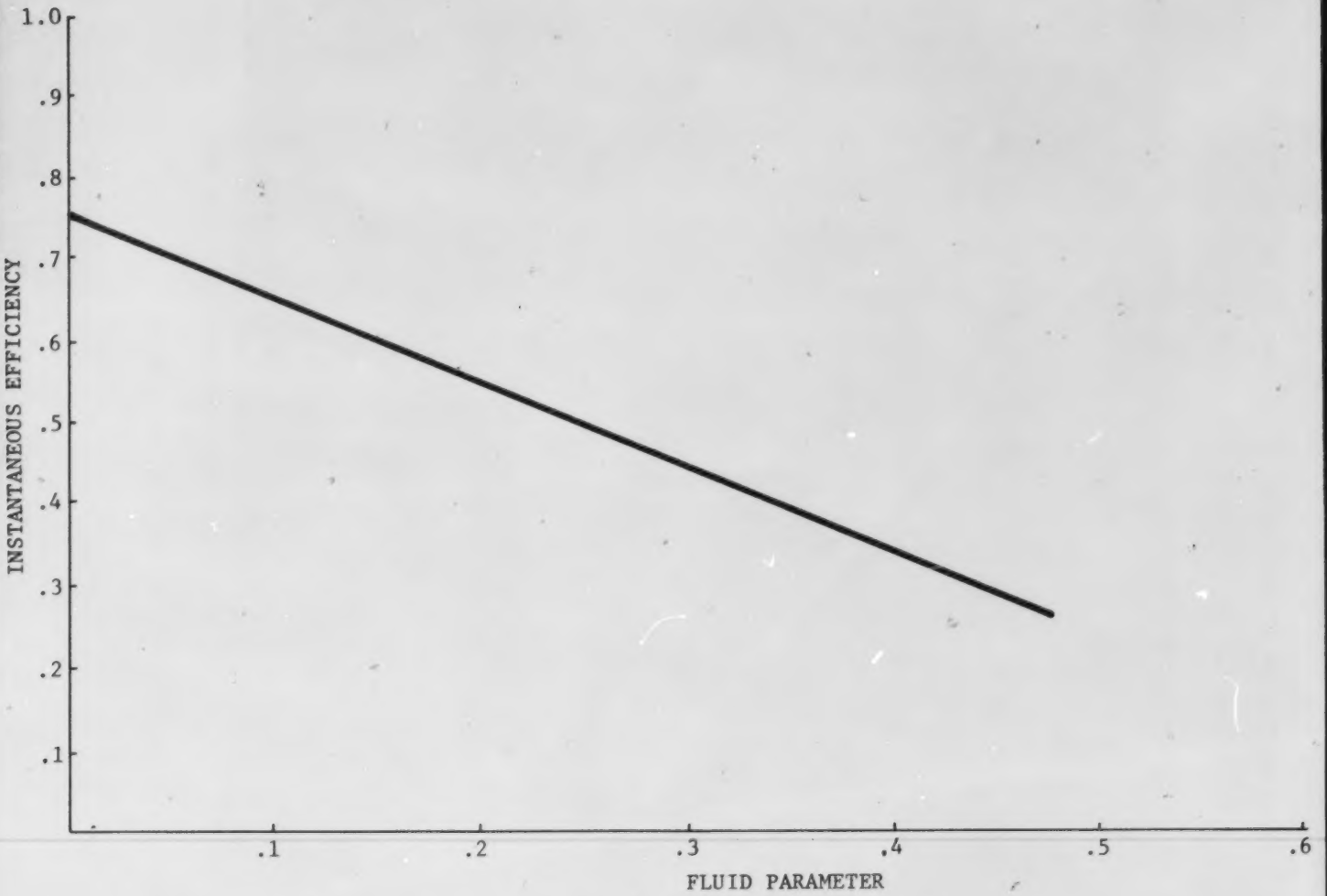


FIGURE B-3
COLLECTOR EFFICIENCY CURVE

The collector efficiency and the incident solar energy are used to calculate the solar energy available per square foot of collector to be applied to the domestic water and space heating loads.

The monthly hot water load is calculated as follows:

HWLOAD = water use (gallons/month) x the specific heat of water x (water set temperature - water main temperature).

The monthly space heating load is the product of the monthly degree day data and the effective building "UA". The effective building UA equals the design space heating load divided by the design temperature difference (indoor - ambient). B-4 contains a summary of the major system parameters and the thermal analysis for our example.

The system size is optimized by minimizing the life cycle cost of the solar system. System sizes are selected in pairs for analysis, using a searching technique called the "golden section."* The optimum is attained when the difference in the two areas under consideration is 32 ft^2 or less.For each system size the thermal analysis and economic data are used to calculate the cash flow for each year and the resulting life cycle cost for the solar system and the life cycle cost for the conventional fuel costs without solar. Figure B-5 shows the results of this analysis for our example in Washington, D.C. The present worth of each system size (PWSOL) is

*"Optimum Seeking Methods", Douglass J. Wilde, Prentice-Hall, Inc., 1964.

SOLAR ANALYSIS FOR WASHINGTN DC
FUEL COST OF 11.49 $/MBTU, COLLECTOR COST OF 20.00 $/F2

DISCOUNT RATE: 2.50%
EFFECTIVE FEDERAL-STATE INCOME TAX RATE: 30.00%
TRUE PROPERTY TAX RATE: 0.0 %
EFFECTIVE BUILDING UA: 526.60 BTU/DAY-F
HOT WATER USAGE: 80.00 GAL/DAY
WATER SET TEMPERATURE: 140.00 F
FUEL ADJUSTMENT FACTOR: 0.0

****THERMAL ANALYSIS****

TIME	PERCENT SOLAR	INCIDENT SOLAR (MBTU)	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	25.5	8.83	11.01	1.83	871.	37.
FEB	34.7	9.87	9.63	1.65	762.	38.
MAR	49.7	12.51	7.91	1.83	626.	45.
APR	74.0	12.45	3.64	1.77	288.	55.
MAY	94.5	12.38	0.94	1.83	74.	63.
JUN	100.0	13.90	0.0	1.77	0.	65.
JUL	100.0	14.06	0.0	1.83	0.	65.
AUG	100.0	13.88	0.0	1.83	0.	65.
SEP	100.0	12.86	0.42	1.77	33.	64.
OCT	84.9	12.81	2.74	1.83	217.	58.
NOV	53.6	11.58	6.56	1.77	519.	48.
DEC	25.9	8.69	10.54	1.83	834.	38.
YR	50.5	143.81	53.38	21.52	4224.	

FIGURE B-4
EXAMPLE OF SOLAR SYSTEM DESIGN

****ECONOMIC ANALYSIS****
OPTIMIZED COLLECTOR AREA = 291. FT2
INITIAL COST OF SOLAR SYSTEM($)= 5814.

YR	MORT PAYMT	INTRST PAID	DEPRC DEDUCT	PRP.TX PAID	INC.TX SAVED	FUEL EXPNSE	MISC EXPNSE	TOTAL COST	SOLAR SAVNGS
1	541.	494.	0.	0.	148.	426.	116.	935.	-75.
2	541.	490.	0.	0.	147.	469.	123.	986.	-39.
3	541.	486.	0.	0.	146.	516.	131.	1042.	-0.
4	541.	481.	0.	0.	144.	567.	138.	1103.	43.
5	541.	476.	0.	0.	143.	624.	147.	1169.	91.
6	541.	471.	0.	0.	141.	687.	156.	1242.	144.
7	541.	465.	0.	0.	139.	755.	165.	1322.	203.
8	541.	458.	0.	0.	137.	831.	175.	1409.	268.
9	541.	451.	0.	0.	135.	914.	185.	1505.	340.
10	541.	443.	0.	0.	133.	1005.	196.	1610.	420.
11	541.	435.	0.	0.	131.	1106.	208.	1724.	508.
12	541.	426.	0.	0.	128.	1216.	221.	1850.	605.
13	541.	416.	0.	0.	125.	1338.	234.	1988.	713.
14	541.	406.	0.	0.	122.	1472.	248.	2139.	832.*
15	541.	394.	0.	0.	118.	1619.	263.	2305.	964.
16	541.	382.	0.	0.	115.	1781.	279.	2486.	1109.
17	541.	368.	0.	0.	110.	1959.	295.	2685.	1270.
18	541.	354.	0.	0.	106.	2155.	313.	2903.	1447.
19	541.	338.	0.	0.	101.	2370.	332.	3142.	1643.
20	541.	320.	0.	0.	96.	2607.	352.	3404.	1859.

PRESENT WORTH OF YEARLY TOTAL COSTS WITH SOLAR($)= 27233.
PRESENT WORTH OF YEARLY TOTAL COSTS W/O SOLAR($) = 35635.

FIGURE B-5
EXAMPLE OF SOLAR SYSTEM DESIGN

calculated by discounting the yearly total cost of solar. The yearly cost of solar is calculated as follows:

SOLCST = cost of auxiliary fuel required + mortgage payment
+ operating and maintenance costs + property taxes
- [effective income tax rate x
(interest charges
+ property taxes)]*

The present worth of yearly costs without solar (PWCON) is simply the present value of the fuel costs for the conventional system. The asterisk on the right for year 14 indicates the year payback occurs.

For a detailed description of the development of the design charts and the design program see S. A. Klein, W. A. Beckman, and J. A. Duffie, A Design Procedure For Solar Heating Systems, University of Wisconsin, Madison, Wisconsin, 1975.

*For a revenue producing application this term would include the auxilary fuel cost, operating and maintenance costs, and tax depreciation.

APPENDIX C

CITY SUMMARIES

This appendix contains a summary by city of the major systems parameters for each of the solar systems designs developed with FCHART.

The summaries are arranged alphabetically by city. The summary table contains the major system parameters for each cost scenario, application, and conventional system.

In some cases the systems which minimize the life cycle cost satisfy a very small percent of the load with solar. It is quite likely that the use of only area dependent costs of \$20, \$15, and \$10/ft^2 without a fixed cost would be invalid for this end of the size range. To compensate for this effect, solar systems which do not carry a significant portion of the load have been dropped from the analysis. Cases with Insufficient Solar Load (ISL) have been indicated by an asterisk in the city summary sheets. For this analysis the threshold for insufficent solar load has been arbitrarily assumed to be 40 percent for hot water and heat and 50 percent for hot water only.

Appendix E has the complete data of each city. Due to its bulk and limited interest it has been bound separately and may be obtained from NTIS, Port Royal Road, Springfield, Virginia.

SUMMARY OF SOLAR SYSTEMS FOR
ATLANTA, GEORGIA

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 37.42
Combined Load (MBtu/yr) = 58.94

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/FT^2 SCENARIO						
Hot Water:						
Electric	99.	55.75	80.7	3294	211.	196.
Oil	68.	38.52	65.0	695	158.	109.
Gas	*	*	*	*	*	54.
Hot Water & Heat:						
Electric	195.	109.78	56.1	6075	577.	538.
Heat Pump	*	*	*	*	*	230.
Oil	*	*	*	*	*	300.
Gas	*	*	*	*	*	150.
15 $/FT^2 SCENARIO						
Hot Water:						
Electric	118.	66.40	87.3	4179	180.	163.
Oil	87.	49.17	75.5	1266	141.	109.
Gas	*	*	*	*	*	55.
Hot Water & Heat:						
Electric	258.	145.31	64.3	7934	531.	524.
Heat Pump	117.	65.87	41.4	915	298.	238.
Oil	156.	87.83	49.8	2332	355.	300.
Gas	*	*	*	*	*	151.
10 $/FT^2 SCENARIO						
Hot Water:						
Electric	148.	83.63	93.9	8698	147.	286.
Oil	129.	72.98	90.4	3850	129.	160.
Gas	87.	49.17	75.5	1070	96.	80.
Hot Water & Heat:						
Electric	525.	295.81	84.4	18297	582.	785.
Heat Pump	243.	136.92	62.6	4498	353.	337.
Oil	298.	166.37	66.5	7149	407.	437.
Gas	171.	96.21	52.4	1960	254.	220.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water.

SUMMARY OF SOLAR SYSTEMS FOR
BISMARCK, NORTH DAKOTA

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 111.86
Combined Load (MBtu/yr) = 133.38

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/FT^2 SCENARIO						
Hot Water:						
Electric	91.	53.68	76.3	3226	205.	196.
Oil	63.	37.09	61.2	1050	157.	123.
Gas	*	*	*	*	*	40.
Hot Water & Heat:						
Electric	488.	289.19	58.6	13513	1359.	1219.
Heat Pump	246.	145.99	38.5	3446	888.	732.
Oil	266.	157.84	40.6	4021	919.	762.
Gas	*	*	*	*	*	249.
15 $/FT^2 SCENARIO						
Hot Water:						
Electric	119.	70.27	85.9	4069	183.	170.
Oil	91.	53.68	76.3	1641	148.	123.
Gas	*	*	*	*	*	30.
Hot Water & Heat:						
Electric	657.	389.53	68.1	18155	1251.	1219.
Heat Pump	371.	219.85	50.1	5925	859.	732.
Oil	383.	227.17	51.1	6642	876.	762.
Gas	*	*	*	*	*	250.
10 $/FT^2 SCENARIO						
Hot Water:						
Electric	153.	90.77	92.0	8439	157.	288.
Oil	136.	80.52	89.6	4433	138.	180.
Gas	68.	39.55	63.1	421	81.	59.
Hot Water & Heat:						
Electric	1140.	675.93	84.2	43423	1280.	1784.
Heat Pump	814.	482.56	74.7	19543	992.	1069.
Oil	828.	481.48	72.0	19589	1037.	1115.
Gas	*	*	*	*	*	365.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water only.

SUMMARY OF SOLAR SYSTEMS FOR
BOSTON, MASSACHUSETTS

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 71.20
Combined Load (MBtu/yr) = 92.72

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/FT^2 SCENARIO						
Hot Water:						
Electric	144.	65.04	76.7	5500	326.	322.
Oil	*	*	*	*	*	116.
Gas	*	*	*	*	*	101.
Hot Water & Heat:						
Electric	493.	223.08	53.8	14684	1504.	1388.
Heat Pump	*	*	*	*	*	625.
Oil	*	*	*	*	*	501.
Gas	*	*	*	*	*	436.
15 $/FT^2 SCENARIO						
Hot Water:						
Electric	170.	76.92	82.0	6738	281.	322.
Oil	75.	33.92	52.6	681	153.	116.
Gas	*	*	*	*	*	101.
Hot Water & Heat:						
Electric	664.	300.48	62.3	19386	1395.	1388.
Heat Pump	*	*	*	*	*	625.
Oil	*	*	*	*	*	500.
Gas	*	*	*	*	*	436.
10 $/FT^2 SCENARIO						
Hot Water:						
Electric	255.	115.38	94.1	14179	251.	472.
Oil	154.	68.86	77.7	2940	173.	171.
Gas	136.	61.08	73.7	2336	159.	150.
Hot Water & Heat:						
Electric	1144.	517.91	77.8	36233	1380.	1709.
Heat Pump	651.	294.83	61.7	12249	941.	912.
Oil	492.	220.53	51.6	7571	786.	734.
Gas	423.	189.23	47.6	5803	709.	647.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water only.

SUMMARY OF SOLAR SYSTEMS FOR
CHARLESTON, SOUTH CAROLINA

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 25.69
Combined Load (MBtu/yr) = 47.21

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/FT^2 SCENARIO						
Hot Water:						
Electric	116.	67.31	89.6	6216	232.	271.
Oil	61.	35.53	62.8	942	150.	114.
Gas	*	*	*	*	*	45.
Hot Water & Heat:						
Electric	211.	122.43	69.6	10154	551.	594.
Heat Pump	*	*	*	*	*	214.
Oil	109.	63.15	49.2	1498	318.	250.
Gas	*	*	*	*	*	100.
15 $/FT^2 SCENARIO						
Hot Water:						
Electric	133.	77.13	93.7	7221	192.	271.
Oil	89.	51.42	79.0	1533	141.	114.
Gas	*	*	*	*	*	46.
Hot Water & Heat:						
Electric	286.	165.33	78.3	12205	504.	594.
Heat Pump	120.	69.41	52.2	1444	275.	215.
Oil	137.	79.54	56.7	2483	289.	251.
Gas	*	*	*	*	*	101.
10 $/FT^2 SCENARIO						
Hot Water:						
Electric	150.	86.95	96.4	13355	146.	397.
Oil	123.	70.45	90.6	4240	123.	167.
Gas	83.	47.47	75.1	712	89.	67.
Hot Water & Heat:						
Electric	451.	261.25	90.5	25165	478.	870.
Heat Pump	229.	132.56	71.8	5204	310.	313.
Oil	272.	155.90	74.8	6865	330.	366.
Gas	115.	66.10	49.8	1122	174.	146.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water only.

SUMMARY OF SOLAR SYSTEMS FOR
COLUMBIA, MISSOURI

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 63.77
Combined Load (MBtu/yr) = 85.29

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/$FT^2$ SCENARIO						
Hot Water:						
Electric	118.	66.05	84.6	4680	244.	244.
Oil	48.	26.99	49.2	512	137.	103.
Gas	*	*	*	*	*	44.
Hot Water & Heat:						
Electric	354.	198.12	57.1	11250	1035.	969.
Heat Pump	*	*	*	*	*	379.
Oil	*	*	*	*	*	409.
Gas	*	*	*	*	*	172.
15 $/$FT^2$ SCENARIO						
Hot Water:						
Electric	126.	70.66	86.7	5656	198.	244.
Oil	70.	39.06	64.0	1007	129.	103.
Gas	*	*	*	*	*	44.
Hot Water & Heat:						
Electric	482.	270.28	66.0	14568	963.	969.
Heat Pump	*	*	*	*	*	379.
Oil	*	*	*	*	*	409.
Gas	*	*	*	*	*	173.
10 $/$FT^2$ SCENARIO						
Hot Water:						
Electric	161.	90.19	92.0	10982	169.	357.
Oil	126.	69.61	85.4	3266	132.	151.
Gas	66.	36.31	60.5	516	83.	64.
Hot Water & Heat:						
Electric	883.	494.63	83.0	34175	1015.	1419.
Heat Pump	397.	222.17	60.3	7030	585.	554.
Oil	423.	234.14	60.0	7883	609.	598.
Gas	*	*	*	*	*	252.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water only.

SUMMARY OF SOLAR SYSTEMS FOR
DALLAS/FT. WORTH, TEXAS

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 30.40
Combined Load (MBtu/yr) = 51.92

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/$FT^2$ SCENARIO						
Hot Water:						
Electric	89.	55.18	82.6	3137	187.	177.
Oil	45.	27.59	52.9	452	120.	88.
Gas	*	*	*	*	*	
Hot Water & Heat:						
Electric	150.	92.54	56.1	5022	451.	429.
Heat Pump	*	*	*	*	*	161.
Oil	*	*	*	*	*	212.
Gas	*	*	*	*	*	147.
15 $/$FT^2$ SCENARIO						
Hot Water:						
Electric	106.	65.71	88.9	3914	159.	177.
Oil	62.	38.13	66.6	896	110.	87.
Gas	45.	27.59	52.9	230	87.	61.
Hot Water & Heat:						
Electric	226.	139.77	68.2	6519	434.	429.
Heat Pump	68.	42.24	34.0	427	205.	160.
Oil	103.	63.36	45.4	1446	250.	211.
Gas	*	*	*	*	*	147.
10 $/$FT^2$ SCENARIO						
Hot Water:						
Electric	134.	82.77	94.1	7929	133.	260.
Oil	112.	68.74	89.7	2921	112.	129.
Gas	94.	57.72	84.1	1545	97.	89.
Hot Water & Heat:						
Electric	414.	255.33	86.9	15765	444.	627.
Heat Pump	171.	105.59	59.8	2787	258.	235.
Oil	248.	151.42	69.1	4786	313.	310.
Gas	145.	88.36	53.5	2380	226.	214.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water only.

SUMMARY OF SOLAR SYSTEMS FOR
GRAND JUNCTION, COLORADO

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 71.27
Combined Load (MBtu/yr) = 92.79

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/FT^2 SCENARIO						
Hot Water:						
Electric	94.	65.31	90.8	5760	185.	235.
Oil	69.	48.37	78.7	1576	147.	119.
Gas	*	*	*	*	*	46.
Hot Water & Heat:						
Electric	414.	288.70	73.5	17207	994.	1014.
Heat Pump	174.	121.20	45.4	3153	577.	481.
Oil	199.	138.88	49.5	3920	607.	511.
Gas	*	*	*	*	*	197.
15 $/FT^2 SCENARIO						
Hot Water:						
Electric	103.	71.79	93.6	6573	150.	235.
Oil	79.	54.84	84.1	2187	122.	118.
Gas	*	*	*	*	*	45.
Hot Water & Heat:						
Electric	534.	372.44	81.6	21081	887.	1014.
Heat Pump	273.	190.64	59.7	4972	563.	481.
Oil	286.	199.48	61.2	5894	574.	511.
Gas	*	*	*	*	*	196.
10 $/FT^2 SCENARIO						
Hot Water:						
Electric	118.	82.26	96.2	11765	116.	344.
Oil	110.	75.88	93.8	4929	107.	173.
Gas	74.	51.13	80.6	1001	78.	67.
Hot Water & Heat:						
Electric	815.	568.55	93.0	43727	818.	1485.
Heat Pump	554.	386.75	82.8	14678	621.	701.
Oil	581.	399.45	81.3	15628	649.	749.
Gas	222.	152.58	50.9	2410	335.	287.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water only.

SUMMARY OF SOLAR SYSTEMS FOR
LOS ANGELES, CALIFORNIA

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 26.12
Combined Load (MBtu/yr) = 47.64

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/FT^2 SCENARIO						
Hot Water:						
Electric	110.	72.70	95.4	7091	206.	272.
Oil	58.	38.38	69.0	740	131.	93.
Gas	*	*	*	*	*	46.
Hot Water & Heat:						
Electric	235.	155.00	87.2	13960	489.	601.
Heat Pump	107.	70.26	58.2	1473	292.	216.
Oil	107.	70.26	58.2	1451	273.	206.
Gas	*	*	*	*	*	101.
15 $/FT^2 SCENARIO						
Hot Water:						
Electric	110.	72.70	95.4	8001	158.	272.
Oil	74.	48.98	80.2	1253	116.	93.
Gas	*	*	*	*	*	46.
Hot Water & Heat:						
Electric	279.	183.95	92.3	16078	414.	602.
Heat Pump	142.	93.69	69.4	2480	268.	217.
Oil	129.	84.74	65.6	2424	240.	206.
Gas	*	*	*	*	*	102.
10 $/FT^2 SCENARIO						
Hot Water:						
Electric	127.	83.31	98.0	14065	119.	398.
Oil	106.	69.38	93.6	3531	102.	136.
Gas	79.	51.38	81.9	978	81.	67.
Hot Water & Heat:						
Electric	329.	216.32	95.5	29403	328.	881.
Heat Pump	244.	160.53	88.3	7207	272.	316.
Oil	235.	153.20	85.5	6825	249.	302.
Gas	136.	88.88	66.5	1849	169.	149.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water only.

SUMMARY OF SOLAR SYSTEMS FOR
MADISON, WISCONSIN

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 99.37
Combined Load (MBtu/yr) = 120.89

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/FT^2 SCENARIO						
Hot Water:						
Electric	120.	61.88	77.5	4346	268.	258.
Oil	*	*	*	*	*	118.
Gas	*	*	*	*	*	48.
Hot Water & Heat:						
Electric	540.	278.55	55.8	15790	1586.	1452.
Heat Pump	*	*	*	*	*	818.
Oil	*	*	*	*	*	659.
Gas	*	*	*	*	*	269.
15 $/FT^2 SCENARIO						
Hot Water:						
Electric	142.	73.19	83.0	5382	230.	258.
Oil	84.	43.59	64.3	1034	153.	118.
Gas	*	*	*	*	*	48.
Hot Water & Heat:						
Electric	713.	368.16	64.3	21003	1456.	1452.
Heat Pump	366.	188.95	44.9	6004	940.	837.
Oil	*	*	*	*	*	659.
Gas	*	*	*	*	*	269.
10 $/FT^2 SCENARIO						
Hot Water:						
Electric	235.	121.10	96.1	11193	220.	378.
Oil	138.	70.23	80.9	3475	154.	172.
Gas	67.	34.24	54.3	464	91.	70.
Hot Water & Heat:						
Electric	1297.	669.53	81.1	49975	1538.	2126.
Heat Pump	865.	446.35	69.9	20072	1130.	1193.
Oil	690.	351.39	60.6	12842	984.	964.
Gas	*	*	*	*	*	392.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water only.

SUMMARY OF SOLAR SYSTEMS FOR

MIAMI, FLORIDA

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 2.71
Combined Load (MBtu/yr) = 24.23

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/FT^2 SCENARIO						
Hot Water:						
Electric	109.	70.02	94.9	7405	206.	280.
Oil	50.	32.26	61.4	681	124.	92.
Gas	*	*	*	*	*	49.
Hot Water & Heat:						
Electric	123.	78.91	94.3	8243	234.	315.
Heat Pump	68.	43.62	69.6	789	169.	113.
Oil	60.	38.47	63.9	7405	143.	104.
Gas	*	*	*	*	*	55.
15 $/FT^2 SCENARIO						
Hot Water:						
Electric	109.	70.02	94.9	8307	158.	280.
Oil	73.	46.68	78.4	1186	116.	92.
Gas	*	*	*	*	*	48.
Hot Water & Heat:						
Electric	136.	87.24	96.9	9277	189.	315.
Heat Pump	89.	57.10	81.9	1410	153.	114.
Oil	81.	51.95	77.6	1325	130.	104.
Gas	*	*	*	*	*	55.
10 $/FT^2 SCENARIO						
Hot Water:						
Electric	132.	84.45	98.6	14565	121.	410.
Oil	114.	72.60	95.9	3472	106.	135.
Gas	76.	48.40	79.9	1087	81.	71.
Hot Water & Heat:						
Electric	149.	95.57	98.3	16337	138.	461.
Heat Pump	123.	78.91	94.3	4102	140.	166.
Oil	120.	76.47	93.1	3869	116.	152.
Gas	93.	59.20	83.2	1208	95.	80.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water only.

SUMMARY OF SOLAR SYSTEMS FOR

NEW YORK, NEW YORK

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 60.80
Combined Load (MBtu/yr) = 82.32

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/FT^2 SCENARIO						
Hot Water:						
Electric	156.	73.70	82.4	10067	351.	446.
Oil	*	*	*	*	*	110.
Gas	*	*	*	*	*	127.
Hot Water & Heat:						
Electric	605.	286.50	63.8	25061	1676.	1704.
Heat Pump	*	*	*	*	*	667.
Oil	*	*	*	*	*	419.
Gas	*	*	*	*	*	487.
15 $/FT^2 SCENARIO						
Hot Water:						
Electric	188.	89.26	87.2	11433	304.	445.
Oil	76.	35.93	56.4	683	147.	109.
Gas	86.	40.74	61.2	1104	162.	127.
Hot Water & Heat:						
Electric	780.	369.61	70.8	30665	1522.	1704.
Heat Pump	272.	129.05	42.2	4571	766.	667.
Oil	*	*	*	*	*	419.
Gas	*	*	*	*	*	488.
10 $/FT^2 SCENARIO						
Hot Water:						
Electric	284.	134.81	96.7	21419	271.	652.
Oil	137.	64.54	77.5	2827	156.	160.
Gas	137.	64.54	77.5	3720	162.	186.
Hot Water & Heat:						
Electric	1474.	698.70	87.8	66450	1594.	2495.
Heat Pump	683.	323.67	67.1	15295	952.	974.
Oil	406.	190.55	50.6	6156	658.	613.
Gas	477.	224.08	54.9	8359	740.	714.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water only.

SUMMARY OF SOLAR SYSTEMS FOR

SEATTLE, WASHINGTON

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 55.91
Combined Load (MBtu/yr) = 77.43

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/FT^2 SCENARIO						
Hot Water:						
Electric	*	*	*	*	*	60.
Oil	*	*	*	*	*	113.
Gas	*	*	*	*	*	86.
Hot Water & Heat:						
Electric	*	*	*	*	*	217.
Heat Pump	*	*	*	*	*	81.
Oil	*	*	*	*	*	407.
Gas	*	*	*	*	*	312.
15 $/FT^2 SCENARIO						
Hot Water:						
Electric	*	*	*	*	*	60.
Oil	*	*	*	*	*	112.
Gas	*	*	*	*	*	87.
Hot Water & Heat:						
Electric	*	*	*	*	*	217.
Heat Pump	*	*	*	*	*	81.
Oil	*	*	*	*	*	406.
Gas	*	*	*	*	*	312.
10 $/FT^2 SCENARIO						
Hot Water:						
Electric	83.	35.56	52.2	531	115.	88.
Oil	141.	60.48	69.6	2433	174.	165.
Gas	101.	42.98	57.9	1382	142.	127.
Hot Water & Heat:						
Electric	*	*	*	*	*	316.
Heat Pump	*	*	*	*	*	118.
Oil	325.	138.48	44.0	5494	618.	596.
Gas	*	*	*	*	*	457.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water only.

SUMMARY OF SOLAR SYSTEMS FOR

WASHINGTON, D.C.

Hot Water Level (MBtu/yr) = 21.52
Heating Load (MBtu/yr) = 53.38
Combined Load (MBtu/yr) = 74.90

CONVENTIONAL SYSTEM USED FOR COMPARISON	COLLECTOR SIZE (FT^2)	ANNUAL INCIDENT SOLAR ENERGY (MBTU)	LOAD BY SOLAR (%)	SOLAR SAVINGS ($)	1st YEAR COST SOLAR ($)	1st YEAR COST CONVENTIONAL ($)
20 $/FT^2 SCENARIO						
Hot Water:						
Electric	124.	62.42	79.0	3993	269.	60.
Oil	41.	20.47	37.9	235	136.	102.
Gas	*	*	*	*	*	69.
Hot Water & Heat:						
Electric	291.	143.81	50.5	8402	935.	860.
Heat Pump	*	*	*	*	*	369.
Oil	*	*	*	*	*	355.
Gas	*	*	*	*	*	241.
15 $/FT^2 SCENARIO						
Hot Water:						
Electric	140.	69.24	83.0	5032	226.	247.
Oil	73.	36.12	58.2	655	138.	102.
Gas	*	*	*	*	*	69.
Hot Water & Heat:						
Electric	418.	206.75	60.7	11289	887.	860.
Heat Pump	*	*	*	*	*	370.
Oil	*	*	*	*	*	355.
Gas	*	*	*	*	*	242.
10 $/FT^2 SCENARIO						
Hot Water:						
Electric	181.	89.72	89.9	10483	195.	362.
Oil	132.	64.60	80.0	2774	145.	149.
Gas	105.	51.29	71.6	1279	120.	101.
Hot Water & Heat:						
Electric	777.	384.51	77.8	27782	960.	1260.
Heat Pump	392.	193.79	58.9	6421	582.	539.
Oil	354.	173.31	54.0	5792	549.	520.
Gas	208.	101.90	40.4	2475	392.	352.

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water only.

APPENDIX D

This appendix contains the years to positive savings and payback for the three scenarios. They are arranged by scenario for hot water only, and for hot water and heat.

In some cases the solar systems which minimize the life cycle cost satisfy a very small percent of the load with solar. It is quite likely that the use of only area dependent costs of \$20, \$15, and \$10/ft^2 without a fixed cost would be invalid for this end of the size range. The numerical values for cases with insufficient solar load have been replaced with asterisks. For this analysis the threshold for insufficient solar load has been arbitrarily assumed to be 50 percent for hot water only and 40 percent for hot water and heat.

TABLE D-I
ECONOMICS OF SOLAR HOT WATER
CURRENT STATUS -20 $/FT^2 INSTALLED SYSTEM COST

	YEARS TO POSITIVE SAVINGS			YEARS TO PAYBACK		
	ELECT.	OIL	GAS	ELECT.	OIL	GAS
ATLANTA	3	8	*	13	20	*
BISMARCK	2	6	*	13	20	*
BOSTON	2	*	*	12	*	*
CHARLESTON	1	7	*	10	18	*
COLUMBIA	1	8	*	12	20	*
DALLAS/FT. WORTH	2	8	*	13	20	*
GRAND JUNCTION	1	5	*	10	16	*
LOS ANGELES	1	7	*	9	19	*
MADISON	2	*	*	13	*	*
MIAMI	1	7	*	9	19	*
NEW YORK CITY	1	*	*	9	*	*
SEATTLE	*	*	*	*	*	*
WASHINGTON, D.C.	3	10	*	13	20+	*

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water.

D-3

TABLE D-II
ECONOMICS OF SOLAR HOT WATER AND HEAT
CURRENT STATUS - 20 $/FT^2 INSTALLED SYSTEM COST

	YEARS TO POSITIVE SAVINGS				YEARS TO PAYBACK			
	ELECT.	H.P.	OIL	GAS	ELECT.	H.P.	OIL	GAS
ATLANTA	3	*	*	*	14	*	*	*
BISMARCK	4	7	7	*	14	19	18	*
BOSTON	3	*	*	*	14	*	*	*
CHARLESTON	1	*	7	*	11	*	19	*
COLUMBIA	3	*	*	*	14	*	*	*
DALLAS/FT.WORTH	3	*	*	*	13	*	*	*
GRAND JUNCTION	1	6	6	*	12	17	17	*
LOS ANGELES	1	7	7	*	10	19	19	*
MADISON	3	*	*	*	14	*	*	*
MIAMI	1	8	7	*	9	20	19	*
NEW YORK CITY	1	*	*	*	12	*	*	*
SEATTLE	*	*	*	*	*	*	*	*
WASHINGTON, D.C.	4	*	*	*	14	*	*	*

* Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water.

TABLE D-III
ECONOMICS OF SOLAR HOT WATER
COST REDUCTION SCENARIO† - 15 $/FT^2 INSTALLED SYSTEM COST

	YEARS TO POSITIVE SAVINGS			YEARS TO PAYBACK		
	ELECT.	OIL	GAS	ELECT.	OIL	GAS
ATLANTA	1	6	*	11	17	*
BISMARCK	1	5	*	11	15	*
BOSTON	1	8	*	10	19	*
CHARLESTON	1	5	*	9	16	*
COLUMBIA	1	6	*	10	17	*
DALLAS/FT. WORTH	1	6	9	11	17	20+
GRAND JUNCTION	1	2	*	8	13	*
LOS ANGELES	1	5	*	7	16	*
MADISON	1	6	*	11	18	*
MIAMI	1	5	*	7	16	*
NEW YORK CITY	1	8	6	8	19	17
SEATTLE	*	*	*	*	*	*
WASHINGTON	1	8	*	11	19	*

† THIS ANALYSIS USES FUEL COSTS ESCALATED AT 10% PER YEAR FROM 1976 TO 1980

*Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water.

TABLE D-IV
ECONOMICS OF SOLAR HOT WATER AND HEAT COST REDUCTION
SCENARIO † - 15 $/FT^2 INSTALLED SYSTEM COST

	YEARS TO POSITIVE SAVINGS				YEARS TO PAYBACK			
	ELECT.	H.P.	OIL	GAS	ELECT.	H.P.	OIL	GAS
ATLANTA	1	8	5	*	12	20	16	*
BISMARCK	2	5	5	*	13	16	16	*
BOSTON	2	*	*	*	12	*	*	*
CHARLESTON	1	7	5	*	10	18	15	*
COLUMBIA	1	*	*	*	12	*	*	*
DALLAS/FT. WORTH	2	9	6	*	12	20+	17	*
GRAND JUNCTION	1	5	4	*	10	15	14	*
LOS ANGELES	1	5	4	*	8	16	15	*
MADISON	2	5	*	*	12	16	*	*
MIAMI	1	6	5	*	7	17	16	*
NEW YORK CITY	1	5	*	*	10	16	*	*
SEATTLE	*	*	*	*	*	*	*	*
WASHINGTON, D.C.	2	*	*	*	13	*	*	*

† THIS ANALYSIS USES THE 1976 FUEL COSTS.

* Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water.

TABLE D-V
ECONOMICS OF SOLAR HOT WATER COST REDUCTION SCENARIO†
FOR 1980 - 10 $/FT^2 INSTALLED SYSTEM COST

	YEARS TO POSITIVE SAVINGS			YEARS TO PAYBACK		
	ELECT.	OIL	GAS	ELECT.	OIL	GAS
ATLANTA	1	1	4	6	10	15
BISMARCK	1	1	7	7	9	19
BOSTON	1	2	2	6	12	13
CHARLESTON	1	1	6	5	9	17
COLUMBIA	1	1	7	6	10	18
DALLAS/FT. WORTH	1	1	3	6	10	13
GRAND JUNCTION	1	1	4	4	8	15
LOS ANGELES	1	1	4	4	9	15
MADISON	1	1	7	7	11	19
MIAMI	1	1	4	4	10	14
NEW YORK CITY	1	1	1	5	12	10
SEATTLE	7	2	4	19	13	14
WASHINGTON, D.C.	1	1	4	6	12	15

† THIS ANALYSIS USES FUEL COSTS ESCALATED AT 10% PER YEAR FROM 1976 TO 1980

TABLE D-VI
ECONOMICS OF SOLAR HOT WATER AND HEAT COST REDUCTION SCENARIO FOR 1980† - 10 $/FT^2 INSTALLED SYSTEM COST

	YEARS TO POSITIVE SAVINGS				YEARS TO PAYBACK			
	ELECT.	H.P.	OIL	GAS	ELECT.	H.P.	OIL	GAS
ATLANTA	1	2	1	5	9	13	11	16
BISMARCK	1	1	1	*	8	11	11	*
BOSTON	1	2	3	4	9	13	14	14
CHARLESTON	1	1	1	6	6	12	11	17
COLUMBIA	1	3	2	*	8	13	13	*
DALLAS/FT. WORTH	1	3	2	3	8	14	12	13
GRAND JUNCTION	1	1	1	5	7	10	10	16
LOS ANGELES	1	1	1	4	5	10	10	15
MADISON	1	1	2	*	8	11	13	*
MIAMI	1	1	1	4	4	9	9	15
NEW YORK CITY	1	1	3	2	7	12	14	13
SEATTLE	*	*	3	*	*	*	13	*
WASHINGTON, D.C.	1	3	3	5	9	14	13	15

† THIS ANALYSIS USES FUEL COSTS ESCALATED AT 10% PER YEAR FROM 1976 TO 1980.

* Insufficient Solar Load, i.e., less than 40 percent Hot Water & Heat or less than 50 percent Hot Water.